New Connector Solutions to Old EMI/RFI Problems

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INTRODUCTION

Engineers designing printed circuit boards often find that EMI or RFI affects the signals in their systems. Many parasitic oscillations or other intrusions of stray EMI or RFI can be illegal or disastrous to the performance of a computer, telephone switch, power supply or other analog/digital device. The military created a group of specifications and test procedures to insure the integrity of their devices, which have much more critical operational needs than typical commercial product requirements.

Now, as commercial system builders advance the capabilities of their products, expand the speed of signal transmission, and require lower rates of error for data integrity, engineers are once again presented with the challenge faced by earlier military hardware designers. How to create a clean series of transmissions in an electrical environment fraught with interference is a major consideration throughout every stage of the design process.

Over the years, many solutions have been utilized, with varying degrees of success and cost. Electronic design trade journals have featured and specified the commercial components and supporting technical data to justify each potential solution. The criteria to evaluate these solutions have not been discussed to any great extent, nor has the state-of-the-art or future technological promise been defined clearly.

The focus of this article is to show how various traditional solutions are used and what new developments exist which could

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have a large impact on the solutions of the past.

The most common connector approaches for dealing with EM or RF interference have been to maintain tight tolerances for connector/backplate/cable interconnections, to attach capacitors and ferrites to the traces or leads, and to use shielding hoods liberally in the component selection process. With new demands for miniaturization, adoption of surface-mount technology, targeted final commercial system pricing, and post-design retrofit of connectors to meet changing governmental regulations, many of these solutions are inadequate or incongruous with newer concerns. From the perspective of the connector selection, the starting point of our analysis of EMI/RFI suppression must be a discussion of ferrites.

WHY ARE FERRITES USED?

For about two decades, interconnection designs have emphasized the use of ferrites for the suppression of unwanted interference. The magnetic and dielectric properties correspond directly to the frequency response characteristics that the connectors in many electronic systems are intended to achieve. As a lowpass filter, the loss tangent of ferrite (in varying shapes, densities and material composition) across the 1 to 1000 MHz range is highly desirable. At low frequencies, ferrite is a low impedance inductor, while at higher frequencies (those in the EM/RF carrier band), absorption of the signal results in attenuation and the ferrite thermally dissipates the undesirable noise, thereby reducing resonance (an advantage over pure capacitor filters). Any impedance at the low end is the result of the material's permeability, and inductive reactance is the key effect. Loss resistance enables the high-frequency suppression to become constant (as measured in ohms) at some moderately high frequency rating. In general, the circuit containing the ferrite has an effective attenuation that relates directly to the ferrite's impedance because the source and load impedance of the circuit are negligible in comparison.

The attenuation of the dB for the ferrite is measured as

$$20 \log_{10} \sqrt{R^2 + \omega L^2}$$

where
R is the resistive portion of the total impedance and
ωL is the reactive component.

In the case where capacitors are added to the filter circuit, a 6 dB/octave rate of change in attenuation beyond the cutoff frequency per filter element will occur, and because two capacitors are commonly used, the ferrite/capacitor arrangement features an increase of 18 dB/octave beyond cutoff attenuation (Figure 1).

*See Advertisement on Page 272.

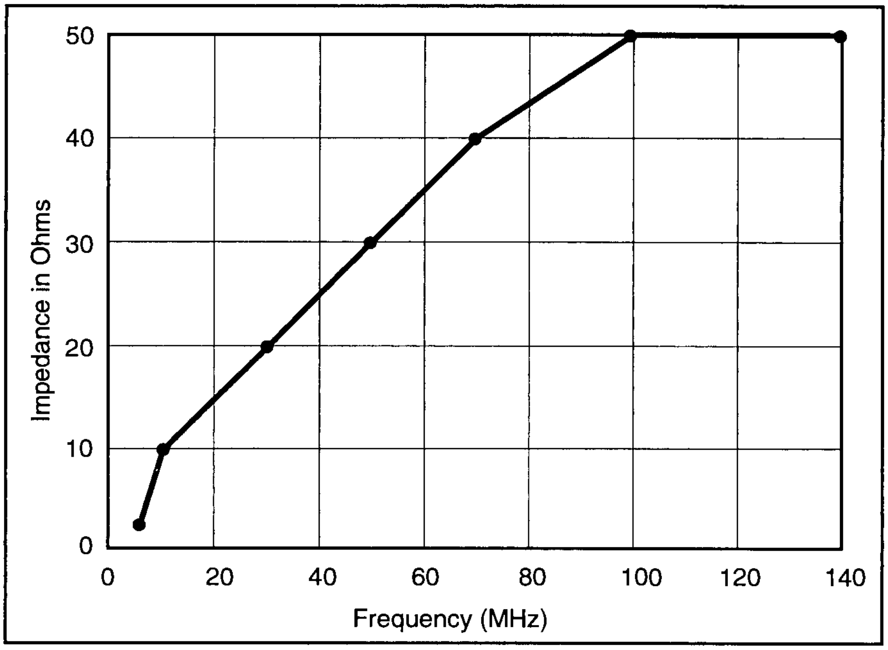

Figure 1. *Filtering Capacity of a Ferrite Block.*

FERRITE MANUFACTURING AND APPLICATION

Ferrites are compounds consisting of 50% to 60% iron oxide (FE_2O_3) and two or more other metals in a cubic ceramic crystal structure. Manganese, nickel and zinc are the most commonly used additives. Nickel-zinc ferrite seems to exhibit the best electrical performance coupled with the most reasonable characteristics for manufacturing.

The manufacturing process includes a chemical process with the metal oxide compound created, a mechanical mixing process to create uniform dispersion of material, and a physical step whereby the resultant compound is sintered to create the final ferrite shape with specific mechanical and electrical characteristics. Machining prior to and following sintering is typical.

The sintering process determines the final shape and properties of the ferrite filter. Shrinkage of over 10% is commonplace. The electrical properties for permeability and loss factors vary significantly, depending on the duration, temperature and pressure of the sintering process. The permeability of the ferrite alters the magnetization and frequency suppression capabilities of the ferrite and specific ferrites show varying Curie temperatures. (The Curie temperature is the temperature above which capacitance fall-off occurs rapidly.)

The resulting shape of the ferrite is typically called a sleeve, bead or core. The most common ferrite pieces used on cable assemblies are sleeves and cores, while connectors have traditionally used ferrite beads on each signal pin. In some cases (especially military applications for connectors), a large bulky connector, such as a filtered Centronics or RS-232 D-Subminiature connector includes ferrite beads, and even capacitors, within the hood of the connector. The final volume of the connector might be twice that of a non-filtered D-Subminiature connector. Connector performance is expected to achieve 90-to 100-dB crosstalk isolation from contact to contact at lower frequencies.

Instead of placing the filter components within the connector, some system designs call for the capacitors and filters to be put onto the PCB itself. In this case, small ferrite beads, sometimes enclosed in a ceramic sleeve, are surface-mounted on the traces. Nearly 50 ohms of impedance can be reached by decreasing the shunt capacitance and increasing the series inductance through a reduction of the center conductor width. Due to soldering limitations, the physical limit of this technique occurs with .020"-wide traces.

IMPROVED FERRITE TECHNOLOGIES AND APPLICATION CONSIDERATIONS

The traditional ferrite material has electrical characteristics established long ago. Manufacturing processes relating to the material are very well-understood. The result of using the small ferrite beads within the connector or on the PCB is time-tested. Design engineers are quick to recognize applications needing this component and can knowledgeably specify the PCB design and component requirements for filtration. Less well-known are the advances in ferrite materials and manufacturing processes and the mechanical advantages to using current solutions which include ferrites. These advances include optimization of electrical properties, simplicity of design, and tradition in the application of D-Subminiature connectors.

From the standpoint of ferrite materials and manufacturing technologies, the newest ferrites are intended to be constructed into thinner membranes, based on the ratio of height versus width, than ever before. Whereas in the past many ferrite specialists were loathe to suggest ferrites manufactured below 5 mm in height or of less than a 1:2 ratio (height to width), the newest ferrites can be pressure-molded and sintered to result in a wide and flat block (planar core) for direct attachment to the body of the D-Subminiature connector with signal pins passing through the block

(Figure 2). Special consideration must be given to the pin hole size to maintain tolerances between the outer diameter (OD) of the pin and the inner diameter (ID) of the hole in the ferrite block. With this accomplishment comes the ability to meet new challenges in system design.

The first, obvious advantage provided by the new ferrites is the possibility of retrofitting an older system to include a D-Subminiature connector with a ferrite block attached. The old PCB does not need new traces, as the new D-Subminiature fits exactly into the pin layout. The height difference is negligible in most applications. The result is EMI/RFI suppression at the connector where none existed before. This capability is especially helpful in telecommunications and power supply products which feature older designs, which are regularly updated to include newer and faster components and which must comply with regulations prohibiting the introduction of noise into the overall system as soon as those regulations are adopted.

Another critical application where the new ferrite D-Subminiature becomes advantageous is in the design of small, handheld consumer devices. The PCB design process for these products is based on the challenge of fitting numerous components into an ever shrinking space. Using a connector with smaller physical dimensions, or omitting the requirement to position a collection of ferrites and capacitors near the connector on the traces, allows much greater flexibility in design. The target size of the final product becomes achievable with less concern for the large connector components. The risk of connector failure due to the failure of one of the capacitor or ferrite components (or traces connecting these components) becomes more remote. In surface-mount applications, it is doubtful whether the filter-filled connector is applicable due to the possibility that connector weight and mechanical pressures during mating connector insertion might be greater than can be handled by a surface-mount solder. The board-mounted filter component option is typically unusable due to slim trace widths. Finally, the price of the D-Subminiature connector with ferrite is significantly lower compared to the expensive and bulky ferrite/capacitor-filled connector of military derivation, and that price reduction is much more important in commercial situations.

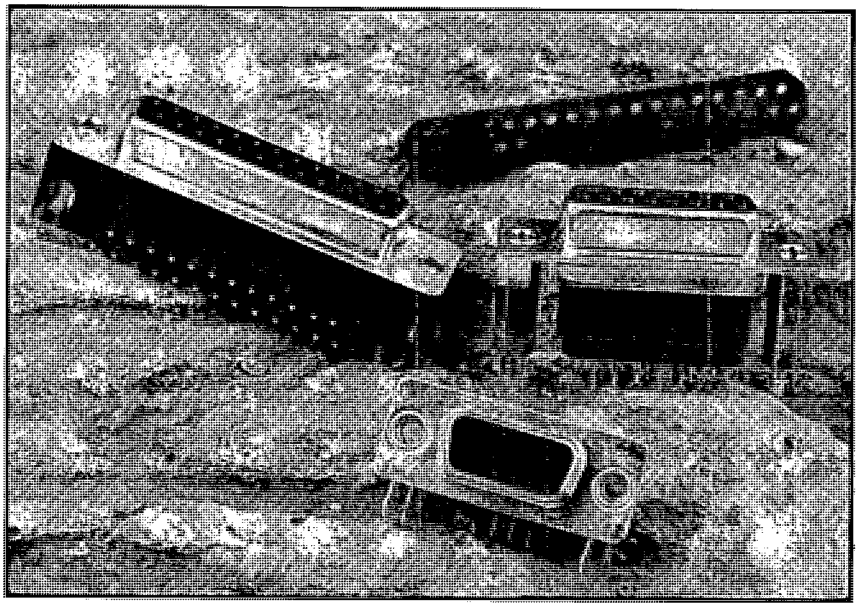

Figure 2. Ferrite Block Used on D-Subminiature Connectors.

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FUTURE SOLUTIONS TO COMBAT EMI/RFI IN THE CONNECTOR

The challenge of suppressing EMI and RFI will continue for the foreseeable future. The connector industry will need to respond to that challenge in many different and creative ways. The effectiveness of hood shields and cable/backplate interconnection will continue to be important. One of the primary emphases will be on the connector itself. Two main areas of future development are predicted: further development of ferrite technology and alternative material uses.

In the first case, ferrite technology advances will continue in various ways. The metals used in addition to iron oxide are likely to be refined significantly or changed. One change already occurring is the conversion from manganese-zinc to magnesium-zinc. Many new isotopes and crystal formations are resulting from space development programs and chemical engineering procedure refinements. The physical sintering process is also being challenged by new compression and molding techniques derived from carbide graphite formation.

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This suggests that in the 1990s, a combination of new ferrites and new manufacturing processes will result in more customized ferrites to address more directly the suppression needs of individual systems. While power transmission ferrites and magnetic recording heads will drive the general ferrite market, the niches for computers and telecommunications will also be addressed by the industry. With the combination of the above uses, ferrite prices will remain very low relative to other ceramic components, yet the volume will be high enough to encourage continued research and development.

Another development that is gaining popularity removes the ferrite material altogether in certain applications. The use of iodine-doped and polarized polymers with conductive fillers is proving to be promising, especially in higher frequency shielding applications. The manufacturing challenge for this family of materials is in the blending of the conductive polymers or iodine-doped materials and the general matrix polymer. The likely result will be an initially expensive material with molding capabilities such that connector cavities can be produced directly out of shield material. This, and previously discussed developments, will turn the connector into a contributing component in the overall system design, rather than a modified convenience item that introduces as many problems as it solves.

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